Grass control outperforms watering for increasing the growth and survival in black cottonwood (*Populus balsamifera* L. spp. *trichocarpa*) stakes in pasture grasses on the Cedar River, WA (2017 Results)

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Summary

This memo presents the 2017 results of an ongoing, controlled experiment on the Cedar River, WA. Our goal was to determine whether the growth and survival of black cottonwood stakes in a sunny, pasture-grass-dominated upland is improved by watering, controlling grass competition with herbicide (glyphosate), or by using both treatments at the same time, relative to an experimental control. The study was done twice; first, in an extremely hot and dry year, and second, under more normal weather conditions.

We found that in each experiment, using glyphosate to reduce competition with dense pasture grasses was the most cost-effective way to increase planting survival and cover, relative to no treatment. Doing no maintenance—the experimental control—was cheap but ineffective. Watering was both costly *and* ineffective.

Accordingly, we intend to use spot-treatment with glyphosate at future projects in uplands where cottonwood stakes are planted in dense pasture grasses. We expect to see, as a result, significantly higher survival and faster cover establishment**.**

We will continue the study until approximately 2025 to see if the patterns we have observed hold over the longer-term.

Why was this study needed?

To stretch restoration funding by finding the most-effective planting and maintenance strategies
The need for riparian restoration is well-established, and the scope of the task is daunting at existing funding levels. We need to test alternative planting and maintenance strategies that aim for high survival and growth at the lowest cost.

[1] *Suggested Citation*: Hartema, L. and J.J. Latterell. 2018. Glyphosate treatment outperforms watering for increasing the growth and survival of black cottonwood (*Populus balsamifera* L. spp. *trichocarpa*) stakes in pasture grasses on the Cedar River, WA (2017 Results). King County Water and Land Resources Division, Seattle, WA.

It's hard to establish trees in sunny, grassy, well-draining uplands
These conditions are common in rural residential parcels and other disturbed sites. Dense pasture grasses are strong competitors with native plantings and make it hard for trees and shrubs to thrive. Common maintenance treatments to cope with grass competition include: mulch (wood or plastic fabric), mechanical/trimming, watering, or glyphosate. We wanted to know which treatment was most cost-effective and improved the survival and cover of cottonwood stakes.

We set up a controlled experiment to answer the following questions:

How effective is watering, glyphosate, or both, relative to no treatment?
Does the use of watering, glyphosate[2], or both increase the survival and growth (cover) of black cottonwood stakes (6 feet tall, ¾ to 1-1.5-inch dia.) in a pasture grass-dominated upland?

How does weather change the answer?
Does the effectiveness of these treatments in the first growing season differ between a hot, dry growing season (2014 Planting) as compared to one with normal rainfall and temperatures (2015 Planting)?

Which treatment is most cost-effective?
Which treatment is the best use of maintenance funds?

Study Site Conditions

Upland area in a river valley
The five-acre site (Parcel 5111400150) is located in rural King County, north of Maple Valley, WA (Figure 1). The site once contained a house, five outbuildings, and a crushed rock driveway, all removed in 2013 (Figure 2). The site is readily accessible from the road.

Sandy loam soils
The site contains Puyallup sandy loam (USDA Web Soil Survey), with patches of small gravel. It is elevated above the 100-year floodplain, at approximately 265-270 feet (a.s.l. NAVD88).

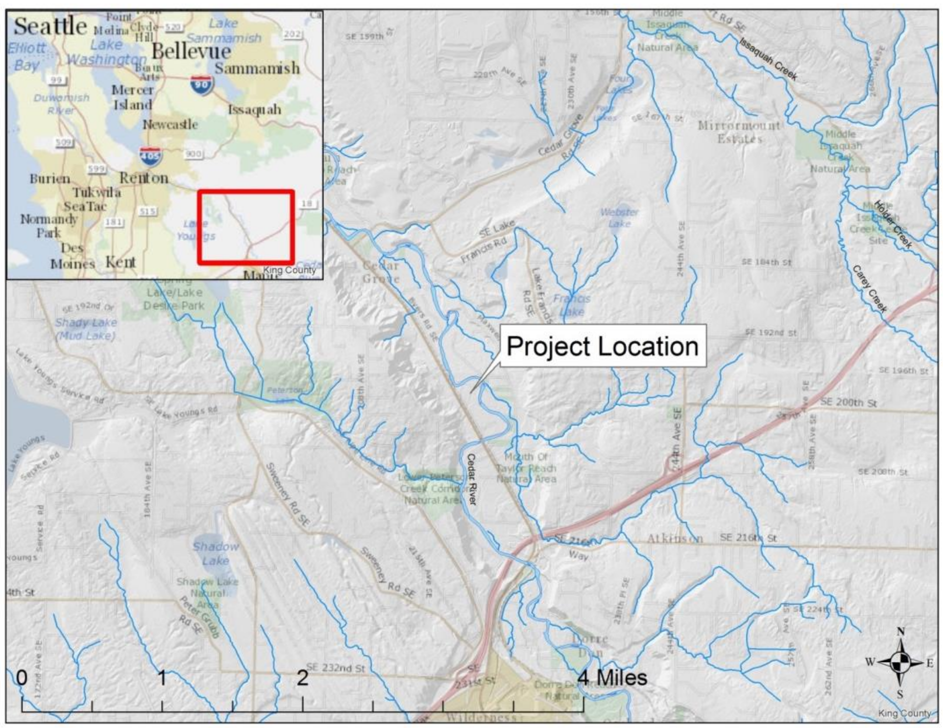

Figure 1. Vicinity Map.

[2]Glyphosate is a systemic herbicide absorbed through foliage and translocated through the plant by the phloem to roots. It inhibits a plant enzyme, essential for amino acids, that controls metabolic processes in plants. Surfactants help glyphosate to penetrate the plant. Among herbicides, glyphosate is considered relatively benign because it degrades and adsorbs to soil.

Grassy

Pre-existing vegetation was dense, native pasture grass with small patches of reed canary grass. Invasive weeds—thistle, Himalayan blackberry, sparse Japanese knotweed—were chemically treated outside of the experimental plots throughout the site.

Full sun

Sun exposure is full, except for patches of shade from trees on the edges of the planting.

What was the experiment?

Randomized plots

Planting plots (25 x 25-ft; Table 1) were established at spatially randomized locations within the site and at least 10 feet away from any other plot to prevent confounding the treatments[3]. Former locations of buildings or obvious road locations were excluded.

Planted each plot with 30 black cottonwood stakes

Stakes were six feet tall and ¾ to 1.5 inches diameter, planted four to five feet on center.

Four treatments

Glyphosate and watering, glyphosate only, watering only, and control (no treatment; Table 1).

Randomized treatments at the plot level

Four treatments were applied at random to the plots. Each treatment was applied to 10 plots in Experiment 1 and to 5 plots in Experiment 2.

Figure 2. Planted area in red.

Repeated experiment to evaluate weather effect

Conducting the experiment in two different years allowed us to investigate the influence of between-year differences in temperature and precipitation (Figure 3)[4]. Plots were monitored to see if differences persisted.

- Experiment 1 (November 2014 Planting): Monitored twice each year in 2015, 2016, and 2017.
- Experiment 2 (December 2015 Planting): Monitored twice in 2016 and 2017.

In general, the first growing season was harsher for the 2014 planting than for the 2015 planting (Figure 3). The first growing season for the 2014 planting was notable for a very hot June and drier than normal conditions from April through July. The first season for the 2015 planting was very warm and dry in April and May but then cooler than normal in June and July, with close-to-normal rainfall. The second growing seasons was generally drier for the 2014 planting than it was for the 2015 planting.

[3] Other native trees and shrubs were planted throughout the parcel but outside the experimental plots.

[4] *In the 2014 Planting (Experiment 1), virtually all the plants in the control and water-only plots died in Year 1. We removed the remaining few live plants, and repeated the experiment in these empty plots. None of the plots in Experiment 2 had been treated with glyphosate in Experiment 1, meaning that the second experiment was not confounded by the first. In Experiment 2, the glyphosate treatment in the first growing season consisted to two applications, instead of one. Otherwise, the only difference between Experiment 1 and 2 was the year of the planting and the nursery providing the stakes.*

Table 1: Experimental Treatments.

Treatment	Description	2014 Planting	2015 Planting
Glyphosate and water	Treated grass/weeds in entire plot with foliar application of glyphosate[5] and watered[6] each plot five to six times from July-August, each time at a rate of approx. one gallon per plant.	10 plots	5 plots
Glyphosate only	Treated grass/weeds in entire plot with foliar application of glyphosate.	10 plots	5 plots
Water only	Watered each plot five to six times	10 plots	5 plots
None (Control)	No water or glyphosate treatment	10 plots	5 plots
	TOTAL	40 plots	20 plots

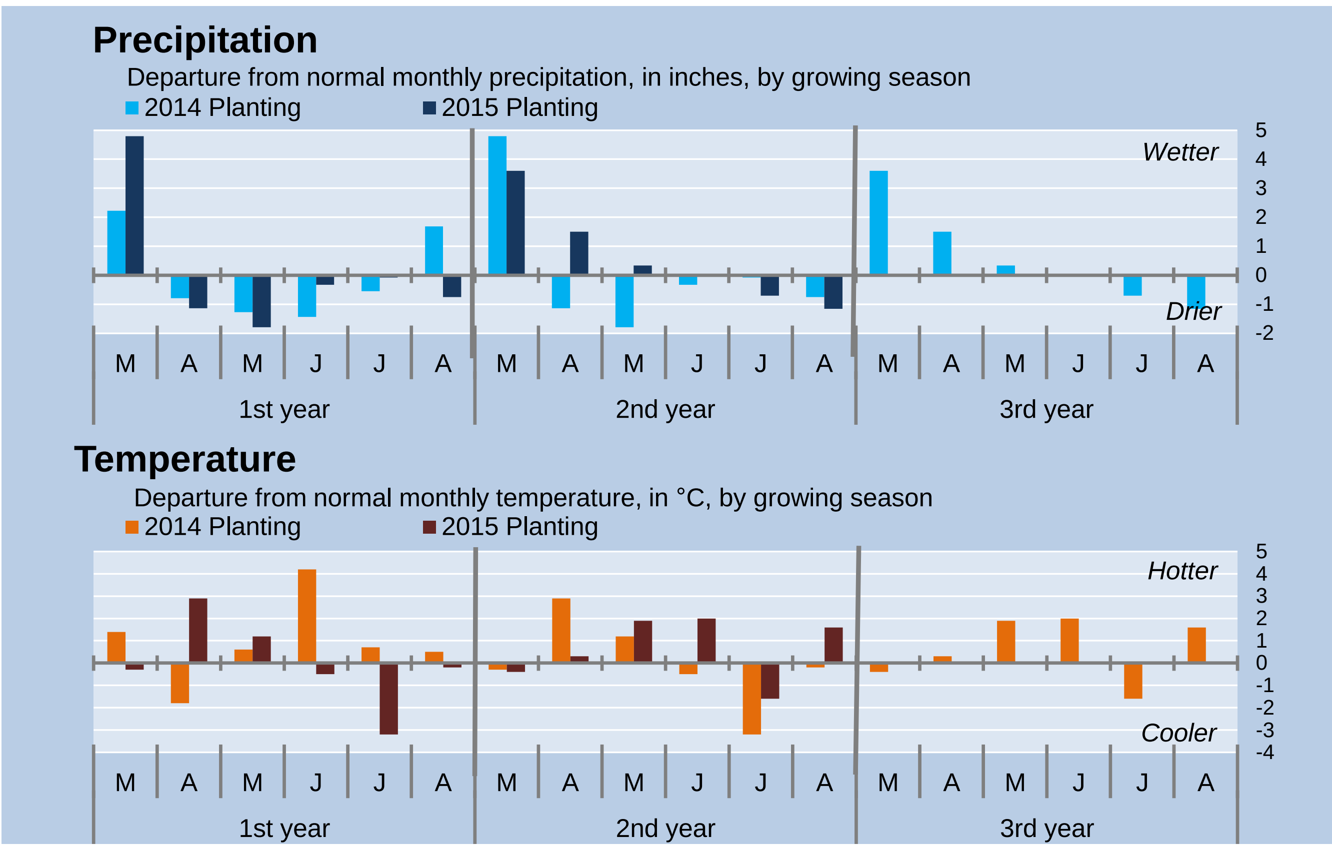

Figure 3. Comparison temperature and precipitation experienced by each planting, relative to 'normal' conditions (zero).

[5] *Used Roundup ProMax (EPA # 524-579) in accordance with labels, for non-aquatic use: 1.5-2% concentration (2-2.5 oz./gal) which includes an "ethoxylated amine" surfactant; added Hi-Light dye/spray indicator at 1/8 oz. per gal. Glyphosate was applied to the 2014 planting once in April 2015, and twice in 2016 (May and August). Two applications were used on the 2015 planting (May and August).*

[6] *Reclaimed water was applied to the 2014 planting six times in 2015. In 2016, reclaimed water was applied once, and water from the Cedar River was used four times for watering; this was the same for both experiments. Reclaimed water likely contains more nitrogen than water withdrawn from the river, which may act as a fertilizer to both grass and trees. It was used when the Cedar River levels were too low to withdraw.*

How was the effectiveness of each treatment measured?

Measured plant survival and canopy cover
Counted live planted trees in each plot prior to treatment in April and after treatment in Aug/Sept of 2015, 2016, and 2017. Measured cover at plot level with GRS Densitometer at 20 equidistant (one foot apart) points along transects crisscrossing each plot. Cover was measured only in Year 2 and 3 for 2014 planting and in Year 1 and 2 for 2015 planting.

Performed statistical analysis and evaluated cost-benefit of each treatment
Compared the average survival and cover among treatments using a one-way Analysis of Variance at $p = 0.05$. Quantified cost-benefit for each treatment by plotting cost vs. cover.

Which was the most effective treatment?

In both experiments the most effective treatment was grass control with glyphosate, either alone or with watering (Figure 4). Survival and cover was significantly improved by grass control (Figure 5). Watering plots treated with glyphosate did not significantly improve survival or cover.

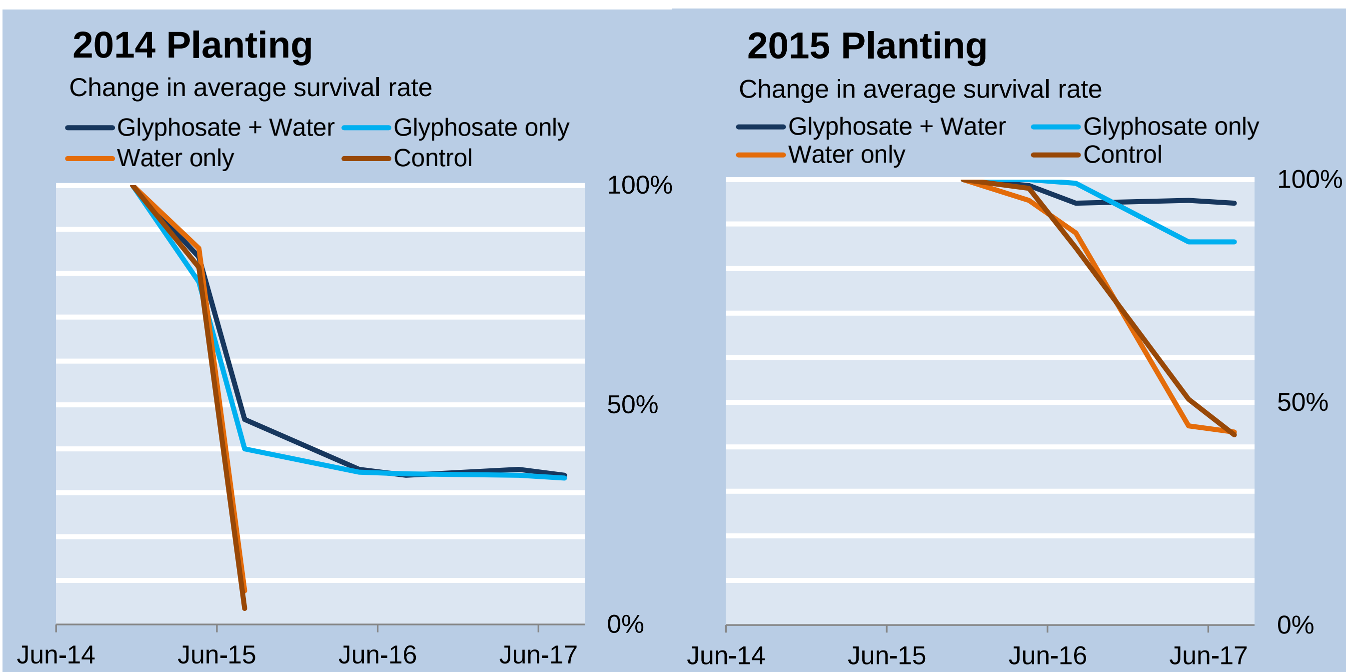

Figure 4. Changes in average survival rate over time, by treatment.

We suspect that glyphosate reduced competition with dense grasses, as intended. Perhaps soil moisture was limiting, but even so, our watering regime was ineffective, in the presence or absence of grasses.

We observed starkly different survival rates and canopy cover between the 2014 and 2015 plantings (Figure 4 and 5). The 2015 planting survived and produced cover at a higher rate.

The difference in survival is probably related to differences in the first growing season: it was generally cooler and wetter for the 2015 planting. The difference in cover probably results from there being more surviving trees, on average, in the 2015 planting.

Watering did not significantly improve survival or cover in in either study, even in dry conditions. Rainfall was mostly below normal in the first growing season for both plantings. But watering was no more effective than doing nothing (Figures 4 and 5).

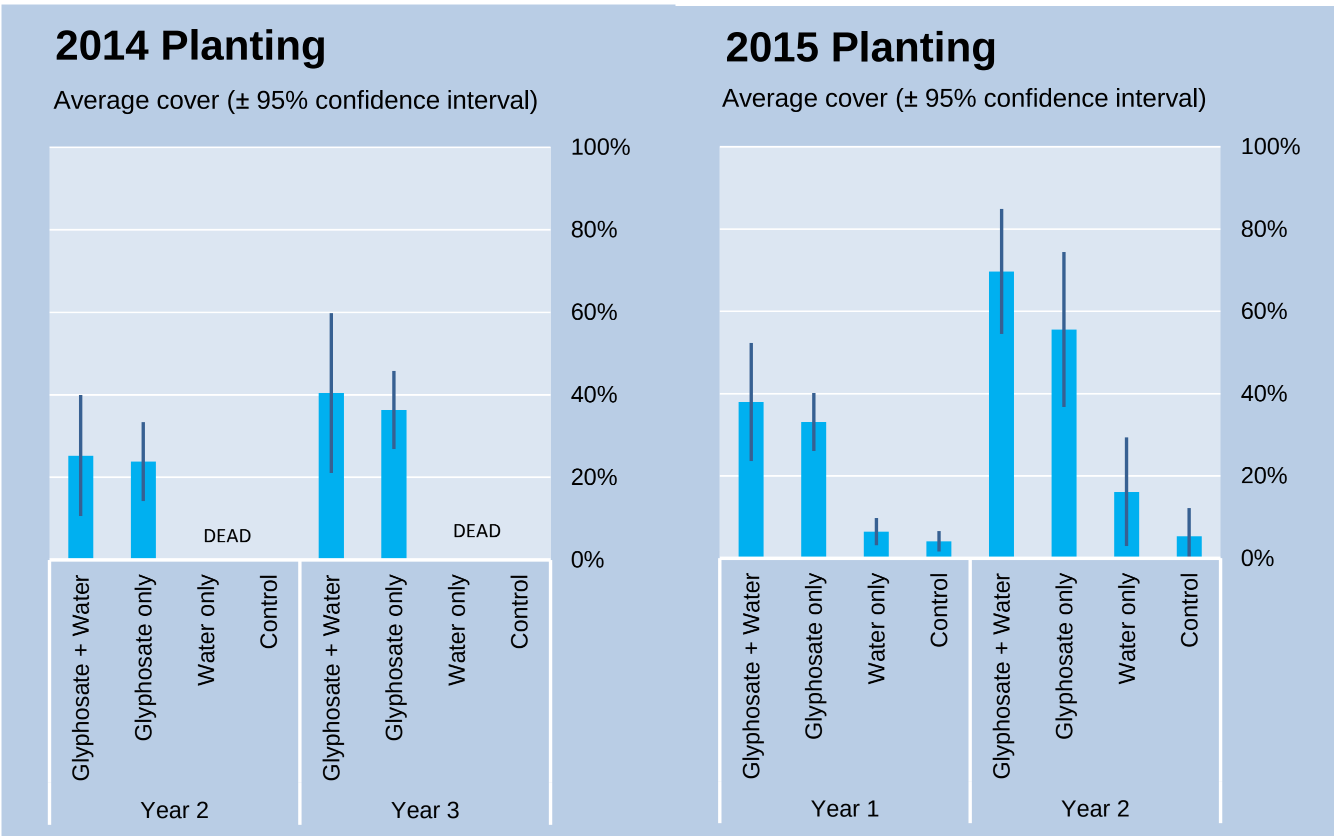

Figure 5. Changes in cover by treatment and year.

Which treatment was most cost-effective?

Glyphosate-only treatment

Maximum cost-effectiveness occurs when cover is high and cost is low (i.e., upper left corner of Figure 6). In both experiments, the glyphosate-only treatment was closest to the ideal condition. Doing nothing—as in the control plots—was cheap but consistently ineffective. Watering alone was costly and ineffective in both experiments. Combining watering with glyphosate greatly reduced the cost effectiveness, compared to glyphosate treatment alone.

Our per-plant watering costs were high, relative to what might be achieved at a site with easy access to water. But in our experience, watering thousands of plants in remote locations lacking utilities is challenging. Our watering costs include time to obtain and transport reclaimed water or connect pumps for river withdrawal, and to find the plots.

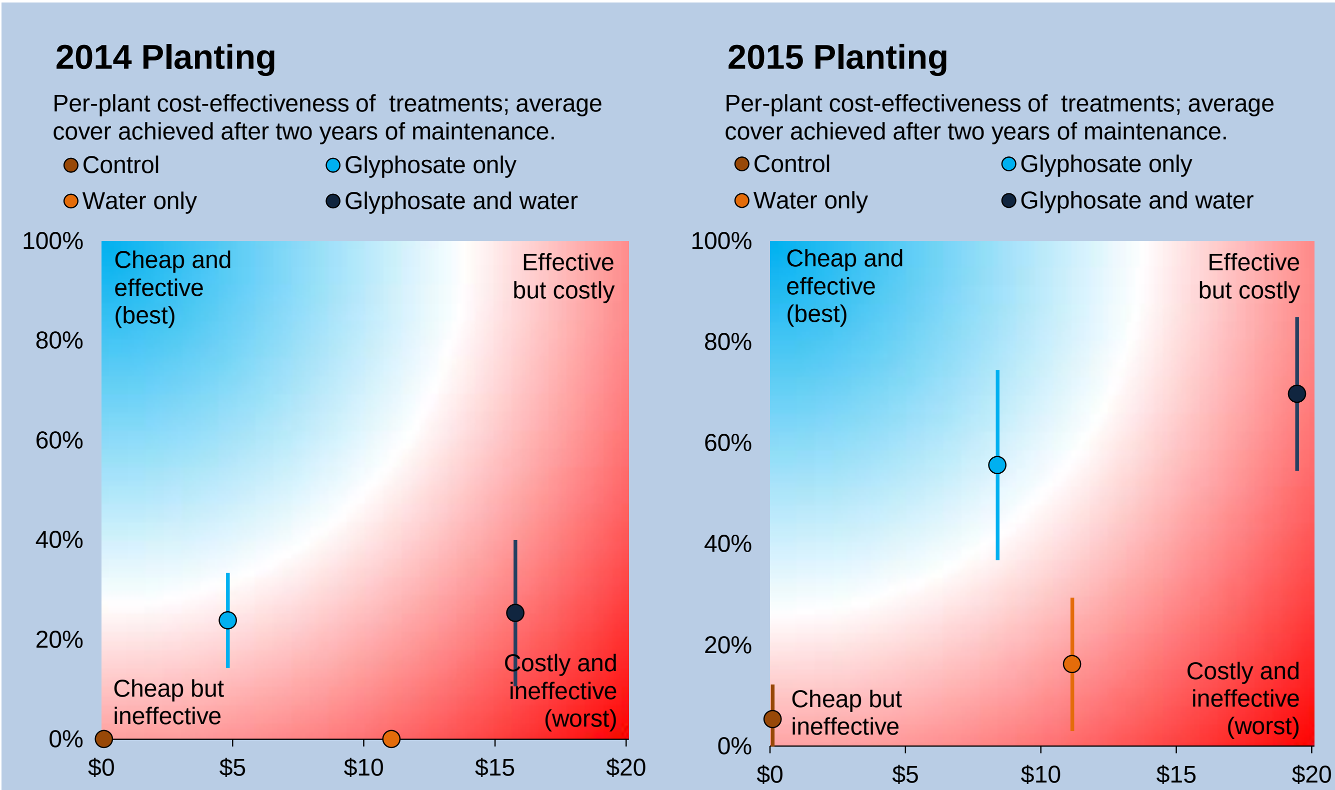

Figure 6. Comparison of cost-effectiveness, per planting, across treatments for each experiment. Error bars show 95% confidence intervals.

Some may speculate that we should have watered more; that using several gallons per plant every week or more would have had a measurable effect on survival or cover. Even if this were true, any gains could be undermined by the added cost, so that watering at a high rate is prohibitively costly. Where glyphosate can't be used, it may be more cost-effective to accept some mortality and invest in replacement plants in the following year.

How can these findings improve our planting projects?

At upland restoration sites, we intend to spot-treat competitive pasture grasses around cottonwood stakes
Reducing competition for soil moisture by eliminating grasses immediately around each plant appears to work far better than watering. We will apply glyphosate to grass in three-foot-diameter rings around each stake in spring (mid- to late April or early May) in the first and second growing seasons, and repeated a second time in years where grass growth occurs more rapidly. We do not plan to broadcast spray an entire site. This treatment should significantly and cost-effectively increase planting survival and cover under a variety of climatic conditions[7].

[7] One caveat is that plots treated with glyphosate appeared to be colonized by more weed species than untreated plots. We are continuing to track plots over time to see if this becomes problematic.

Caveats

Results may vary at different sites

Results of this study should not be extrapolated to sites with different hydrology, topography, soils, weed or grass communities, or land use history.

Results may vary with different plantings

Our results may not be representative of other plant species, sizes or spacing. Plants in this study were installed at four to five feet on-center spacing; cover may have been lower if plants had been installed at lower densities.

We recognize herbicide is controversial

It is beyond the scope of this memo to examine the tradeoffs associated with glyphosate use. We intend to use it sparingly and according to labeled instructions to minimize unintended impacts.